

Claudio
Sangregorio

Dall'atomo ai materiali massivi: proprietà fisiche e dimensioni

*CNR - ICCOM Istituto di Chimica dei
Composti OrganoMetallici*

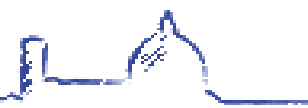
*INSTM Consorzio Interuniversitario Nazionale
per la Scienza e Tecnologia dei Materiali*

Laboratorio di **M**agnetismo **M**olecolare
Dip. di Chimica, Università di Firenze



National Research Council of Italy



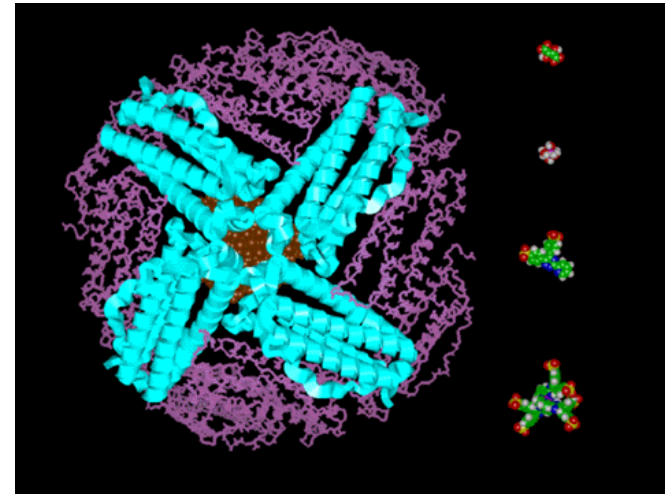


Paleomagnetismo

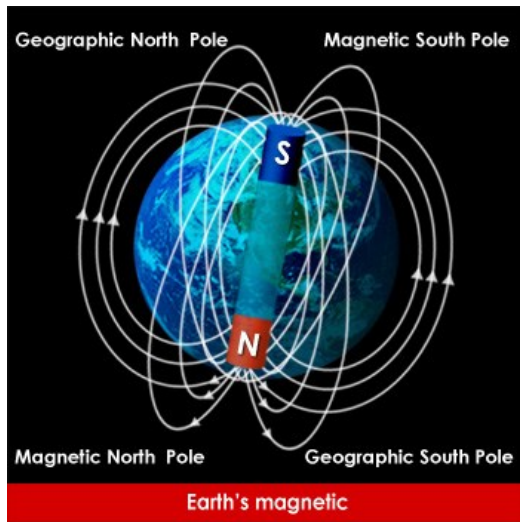
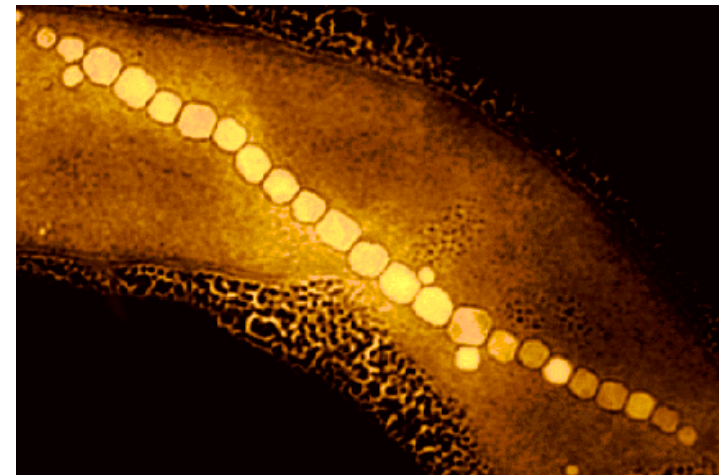


L. Néel Ann. Geophys. 1949

Ferritina



Batteri magnetotattici





Nanomedicina

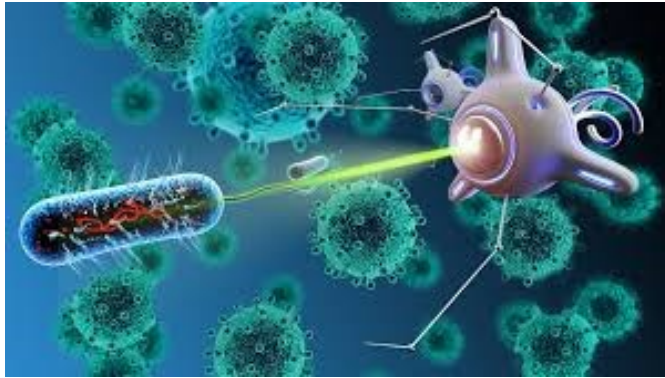


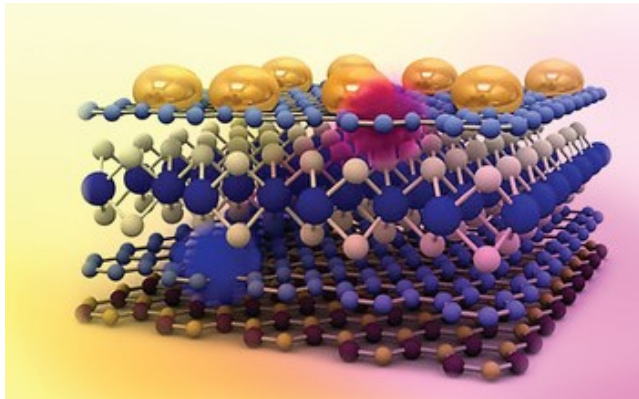
Image Credits | [shutterstock.com/g/gorbovoi81](https://www.shutterstock.com/g/gorbovoi81)

Ambiente

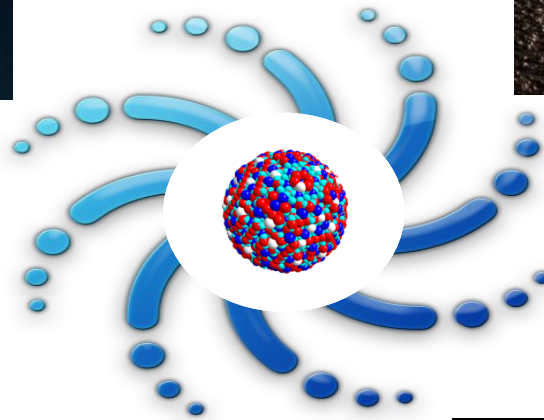


<https://www.azonano.com/article.aspx?ArticleID=3178>

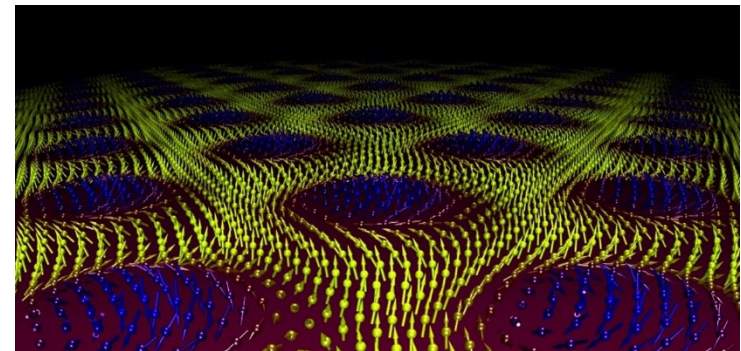
Nanocompositi smart



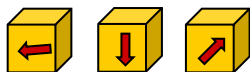
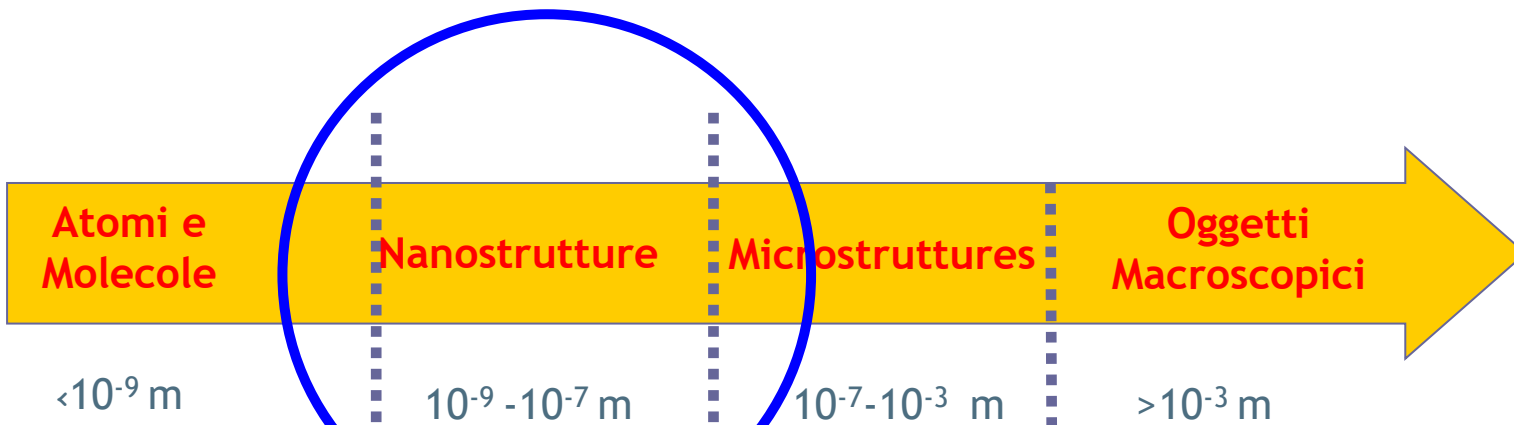
Hybrid Nanocomposites Fundamentals, Synthesis, and Applications Ed. K. Pal 2019 CRC Press



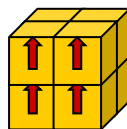
Dispositivi elettronici



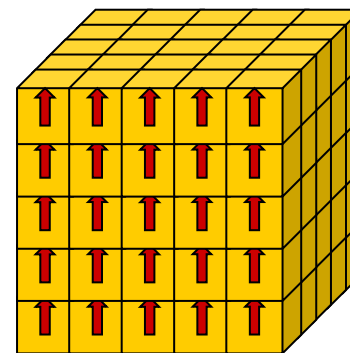
<https://news.cnrs.fr/articles/the-new-challenges-of-spintronics>; © C. PFEIDERER/TUM;



paramagnetism



superparamagnetismo

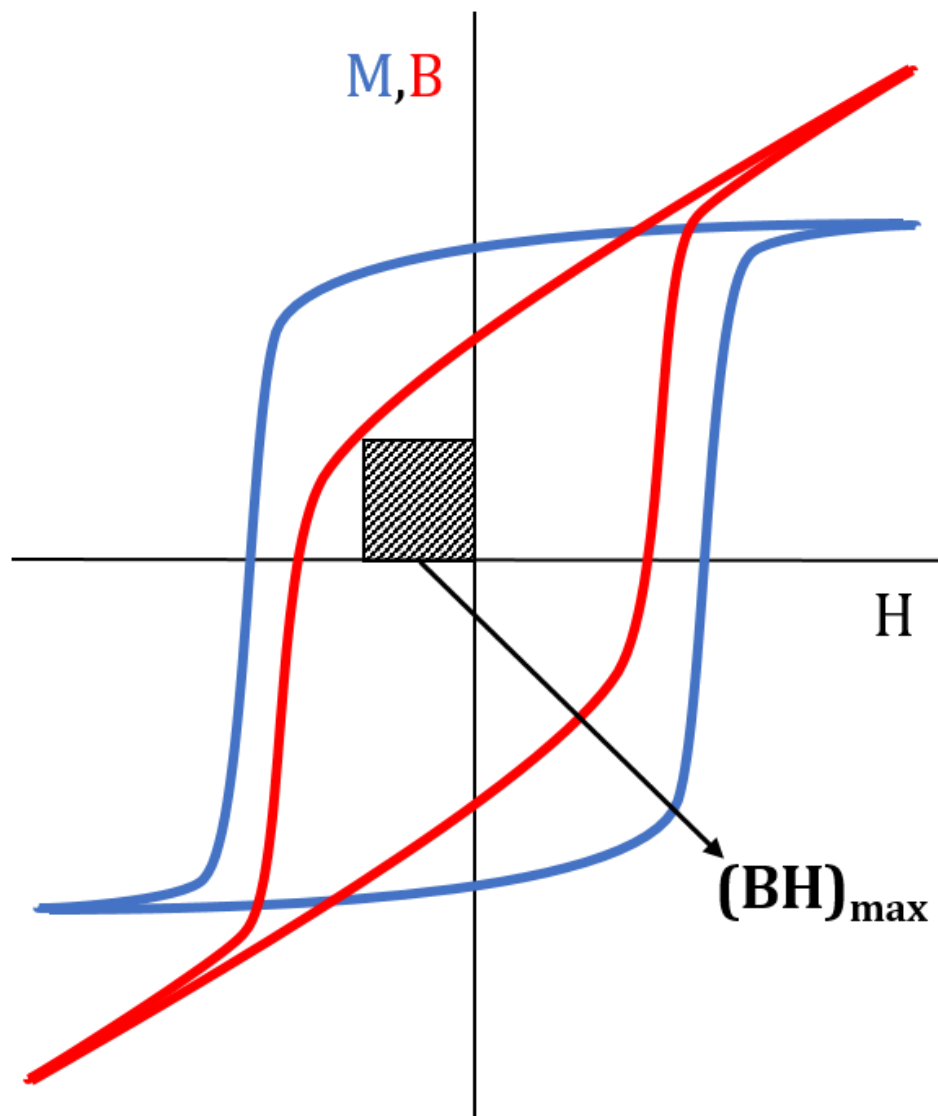
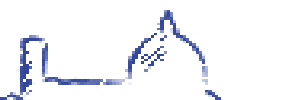


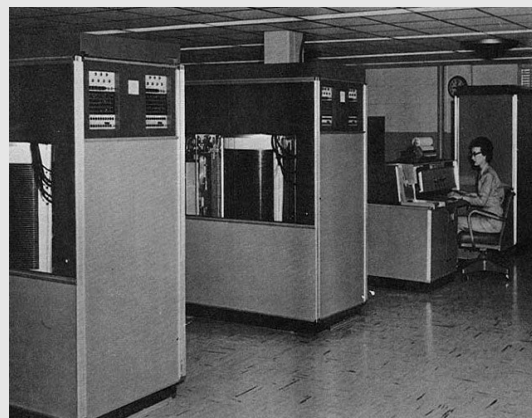
Magnete massivo

Quantomeccanica

????????????

Fisica classica





1956: 1° hard disk - IBM RAMAC

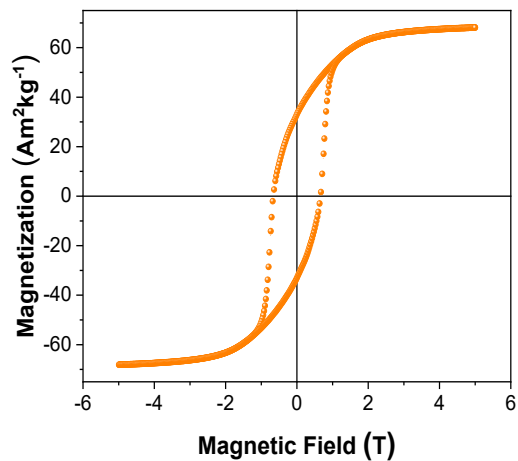
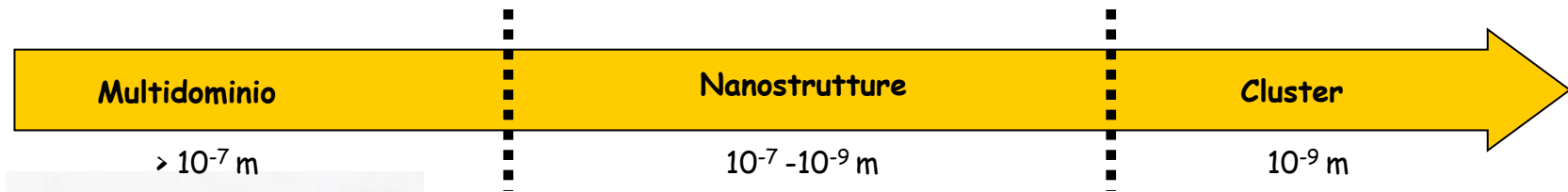


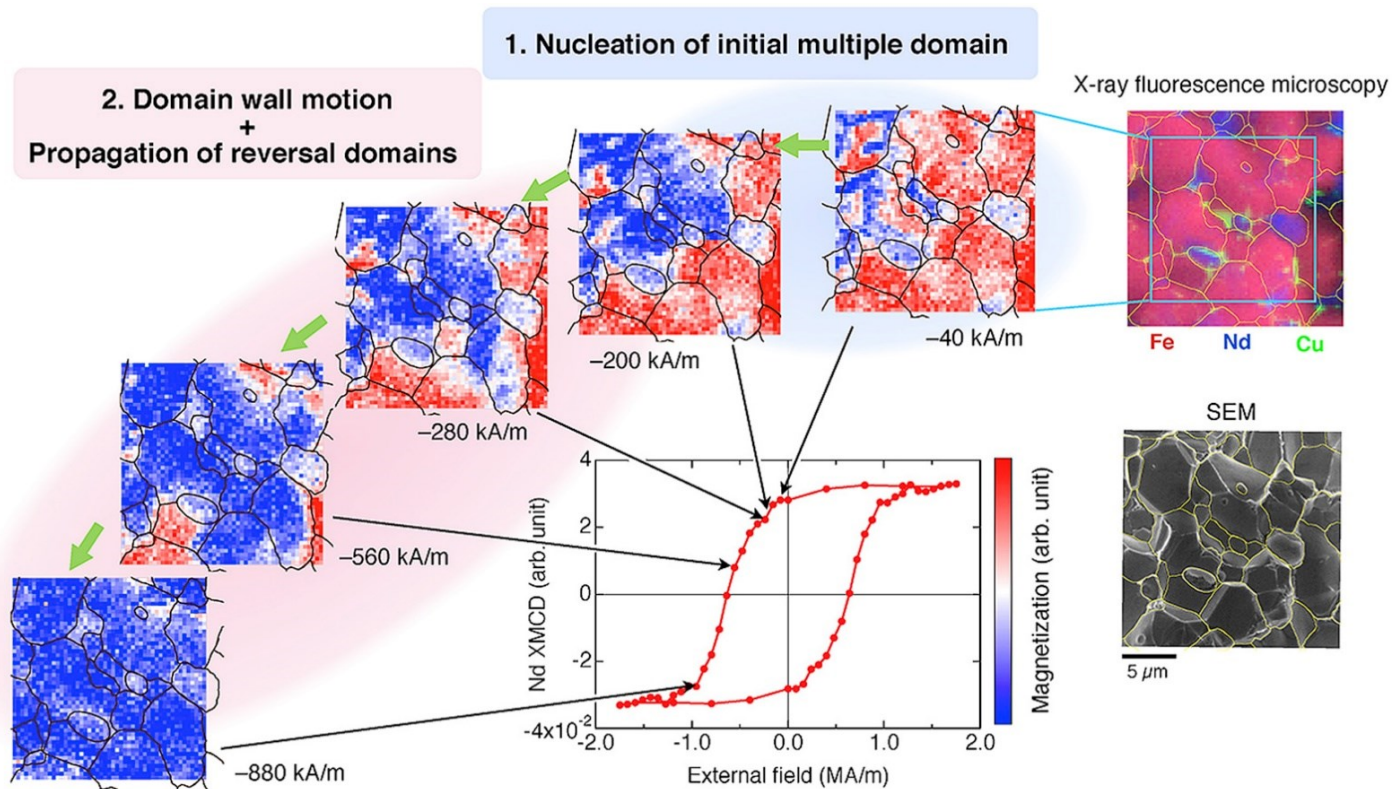
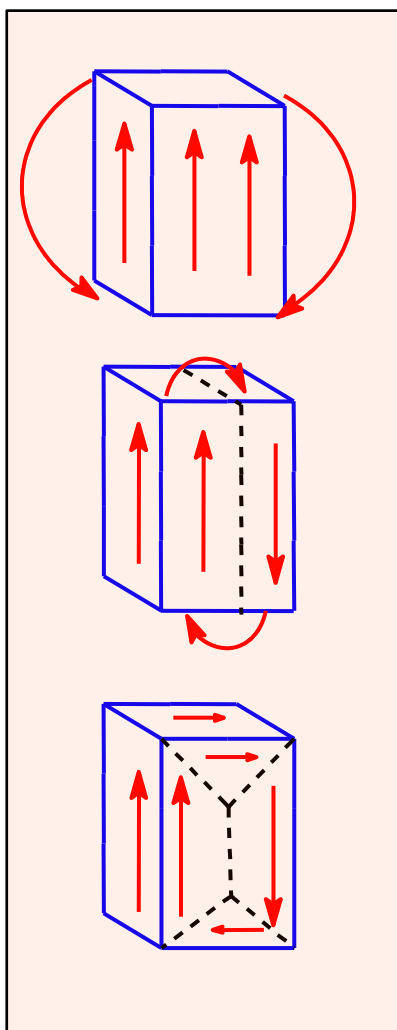
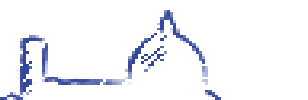
From <https://www.which.co.uk/news/2021/03/5-problems-with-electric-car-charging-and-how-to-fix-them/>



<https://www.magforce.com/home/>

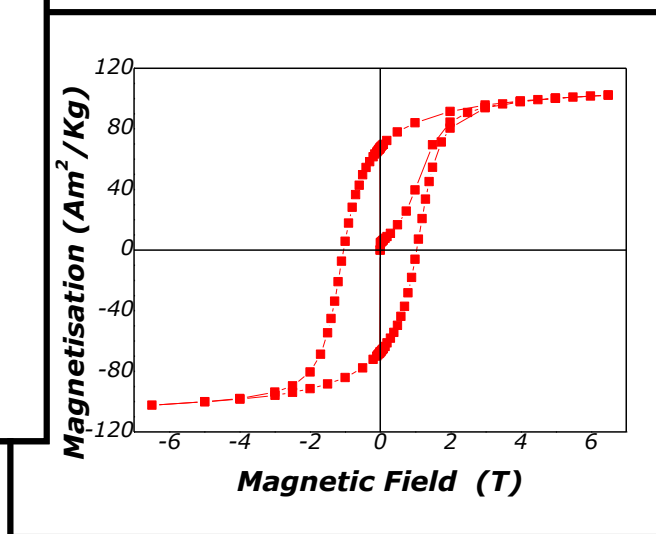
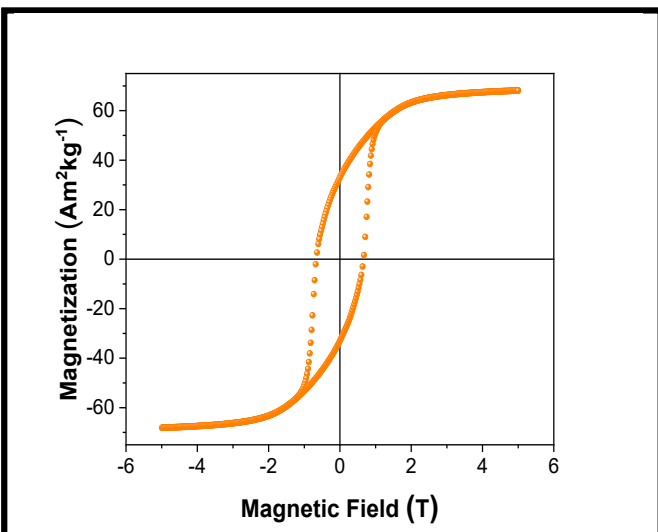
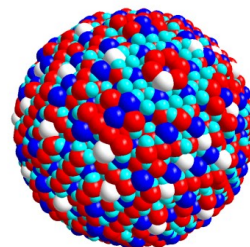
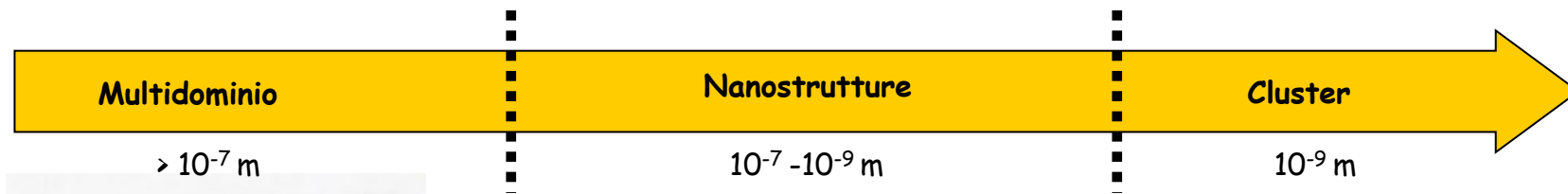
Il ciclo di isteresi



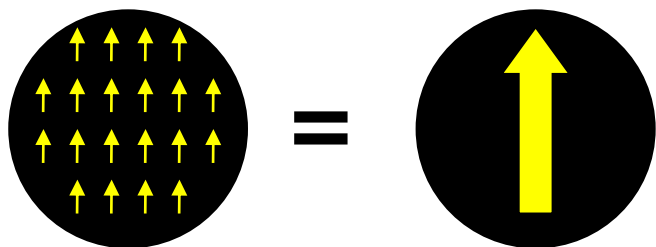


M. Suzuki *et al* Magnetic domain evolution in Nd-Fe-B:Cu sintered magnet visualized by scanning hard X-ray microprobe *Acta Materialia* 2016, 106, 155

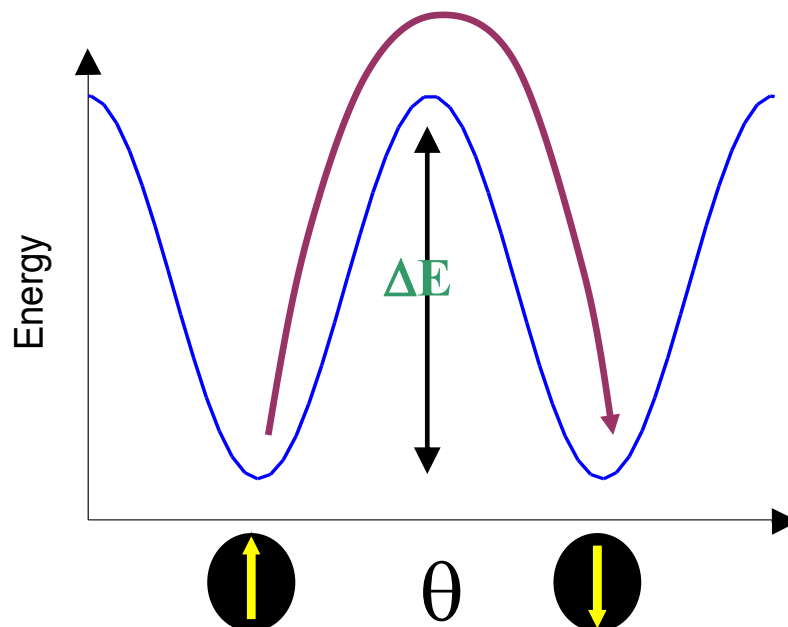
Il ciclo di isteresi



Il ciclo di isteresi nelle nanoparticelle



L'inversione della magnetizzazione avviene attraverso la rotazione coerente di tutti gli spin della nanoparticella

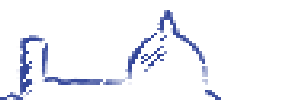


$$\tau = \tau_0 \exp(\Delta E/kT)$$

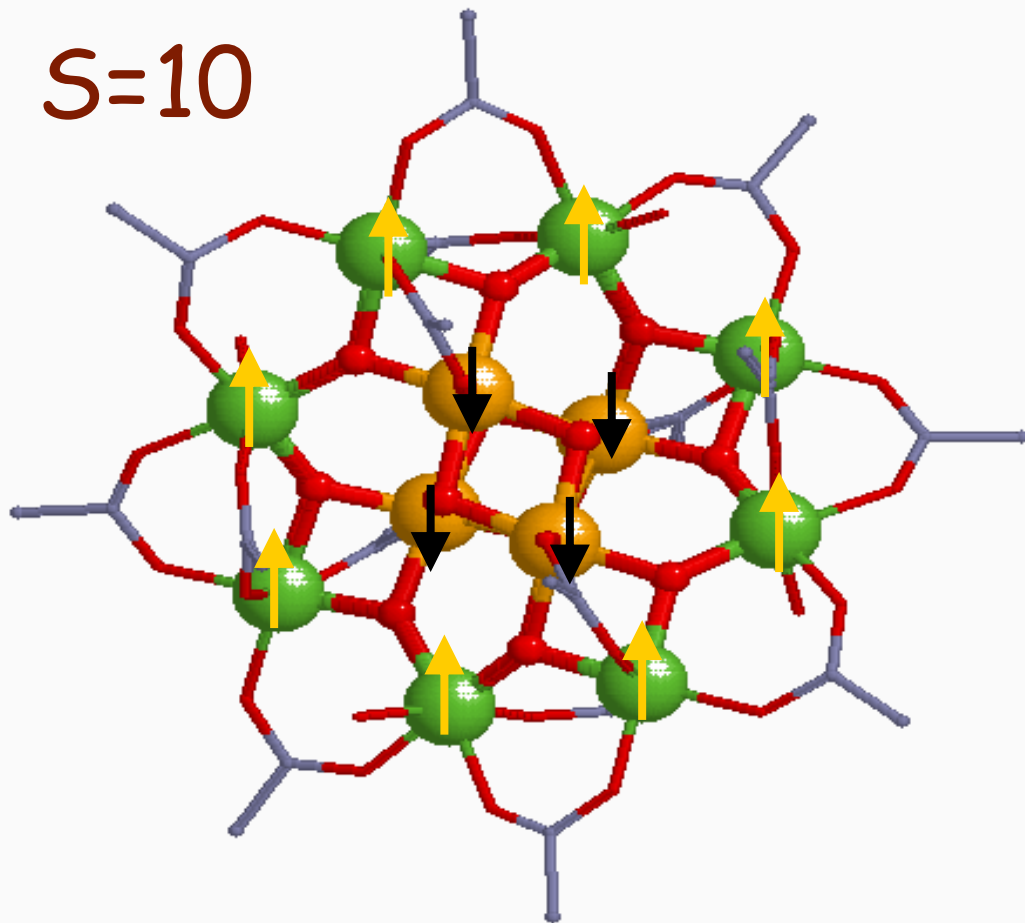
Barriera di energia $\Delta E = k_A V$

k_A = costante di anisotropia, V = volume della particella

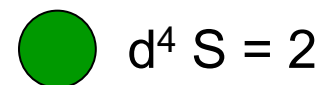
Se ΔE è più piccolo di $k_B T$ M è bloccata in uno dei due «pozzi»



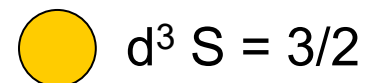
$S=10$



Mn(III)



Mn(IV)



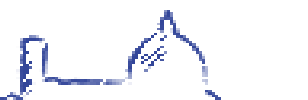
Ossigeno



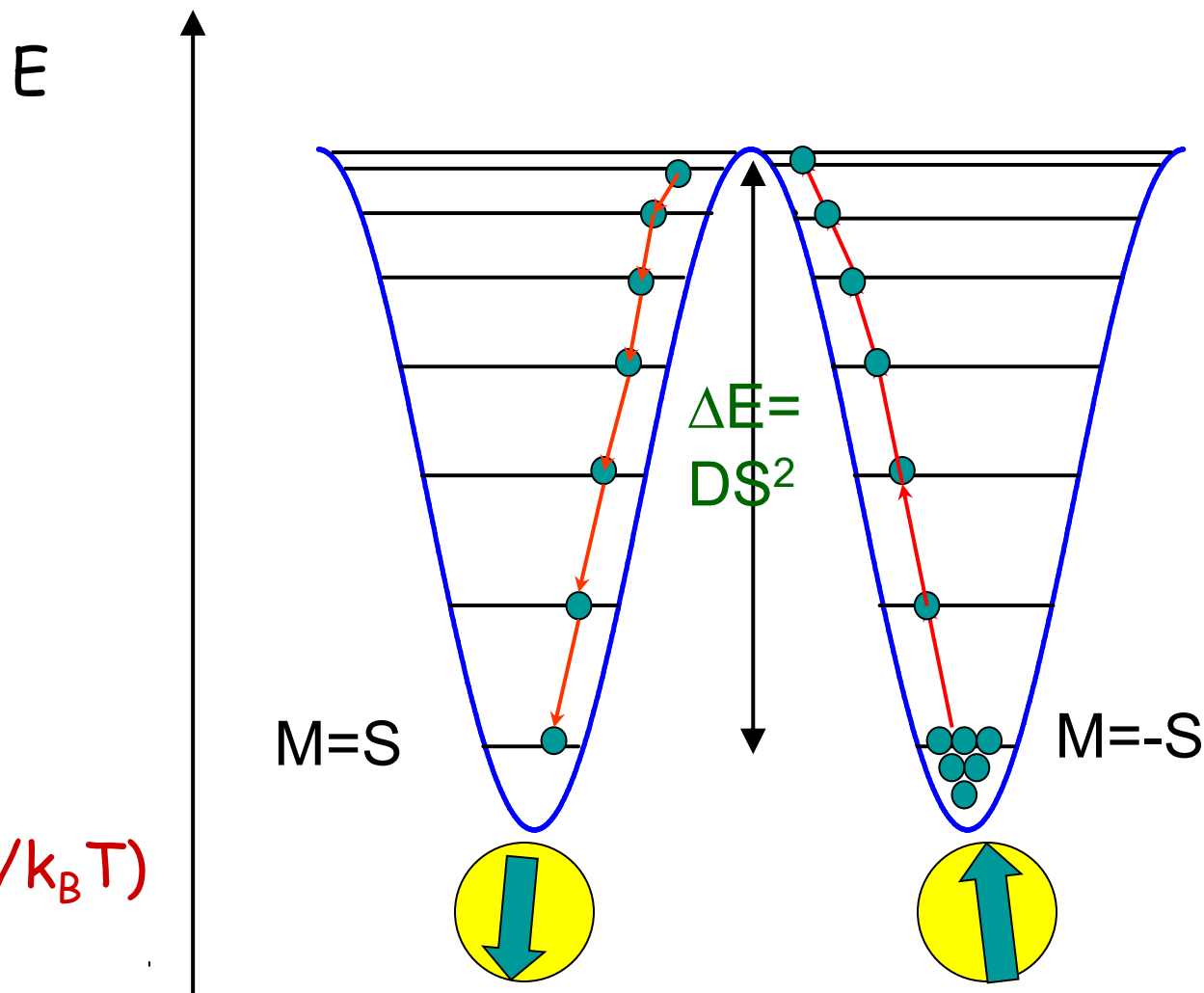
Carbonio



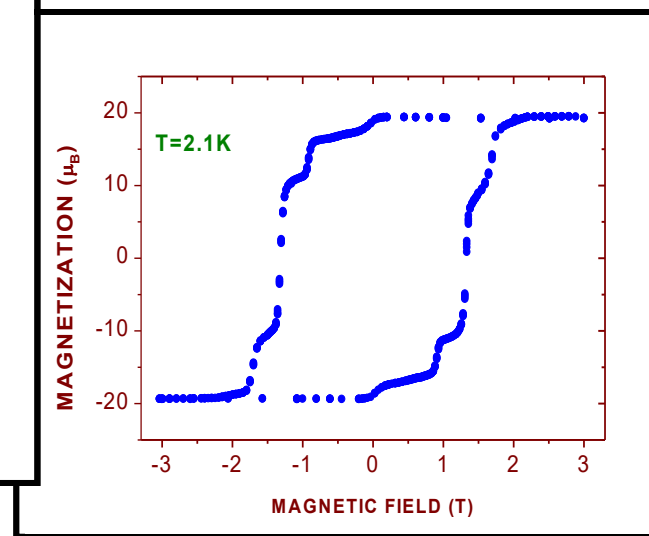
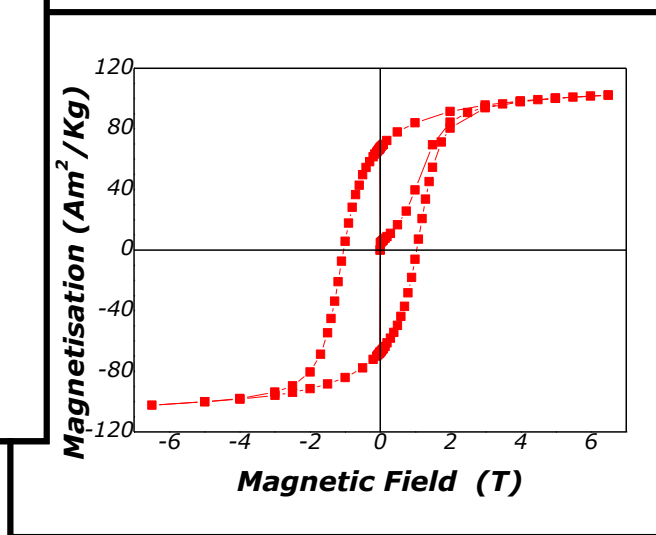
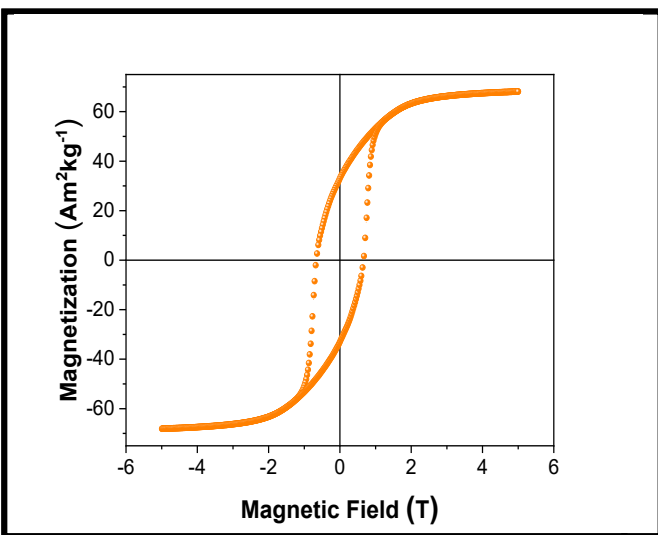
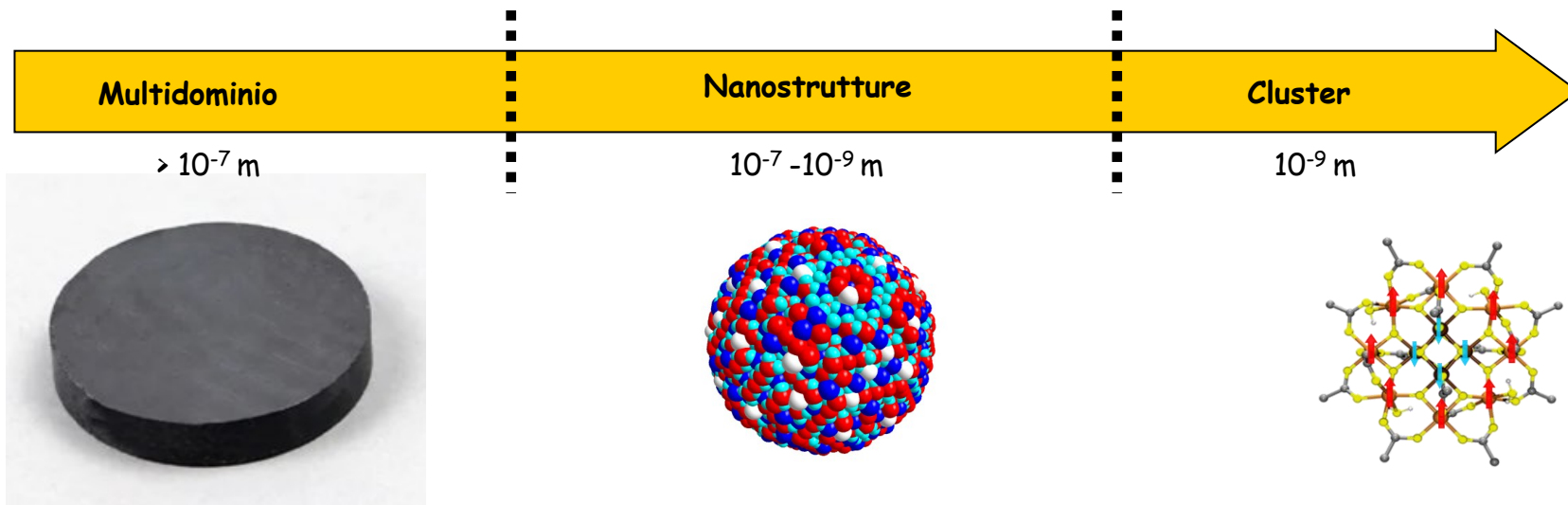
- Simmetria tetragonale
 - Stato fondamentale
- $$S = (8 \times 2 - 4 \times 3/2) = 10$$



Barriera di potenziale $H=DS_z^2$ ($D<0$)



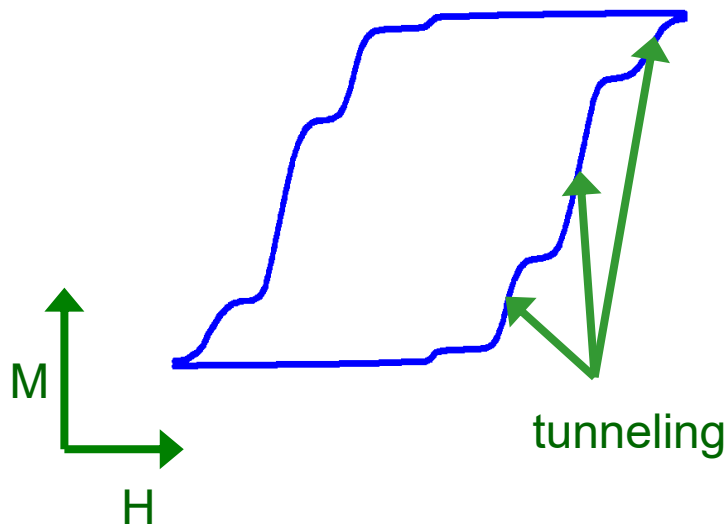
Il ciclo di isteresi



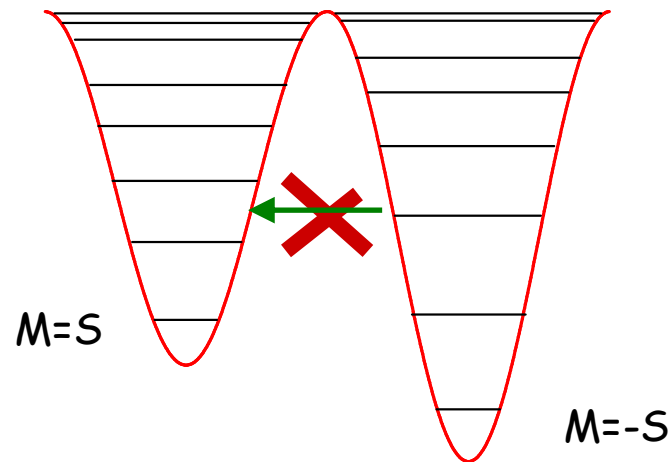
Il ciclo di isteresi nei SMM



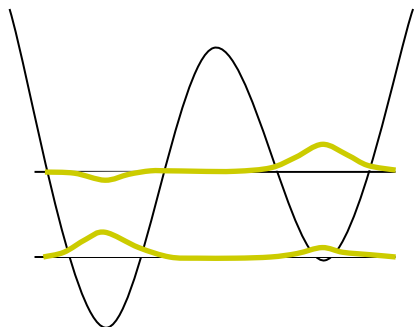
H sopprime il rilassamento per tunneling



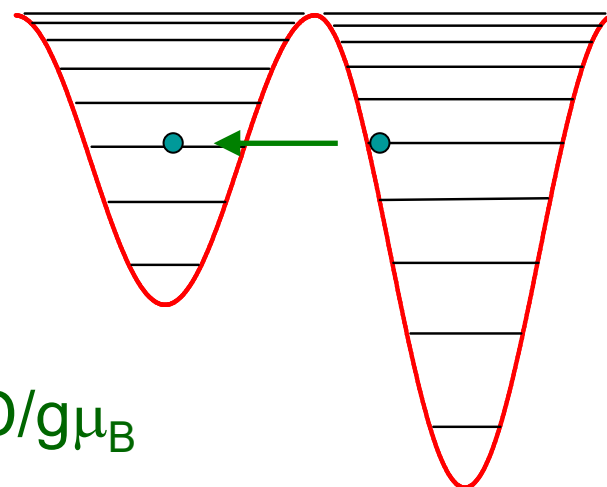
$H \neq 0$

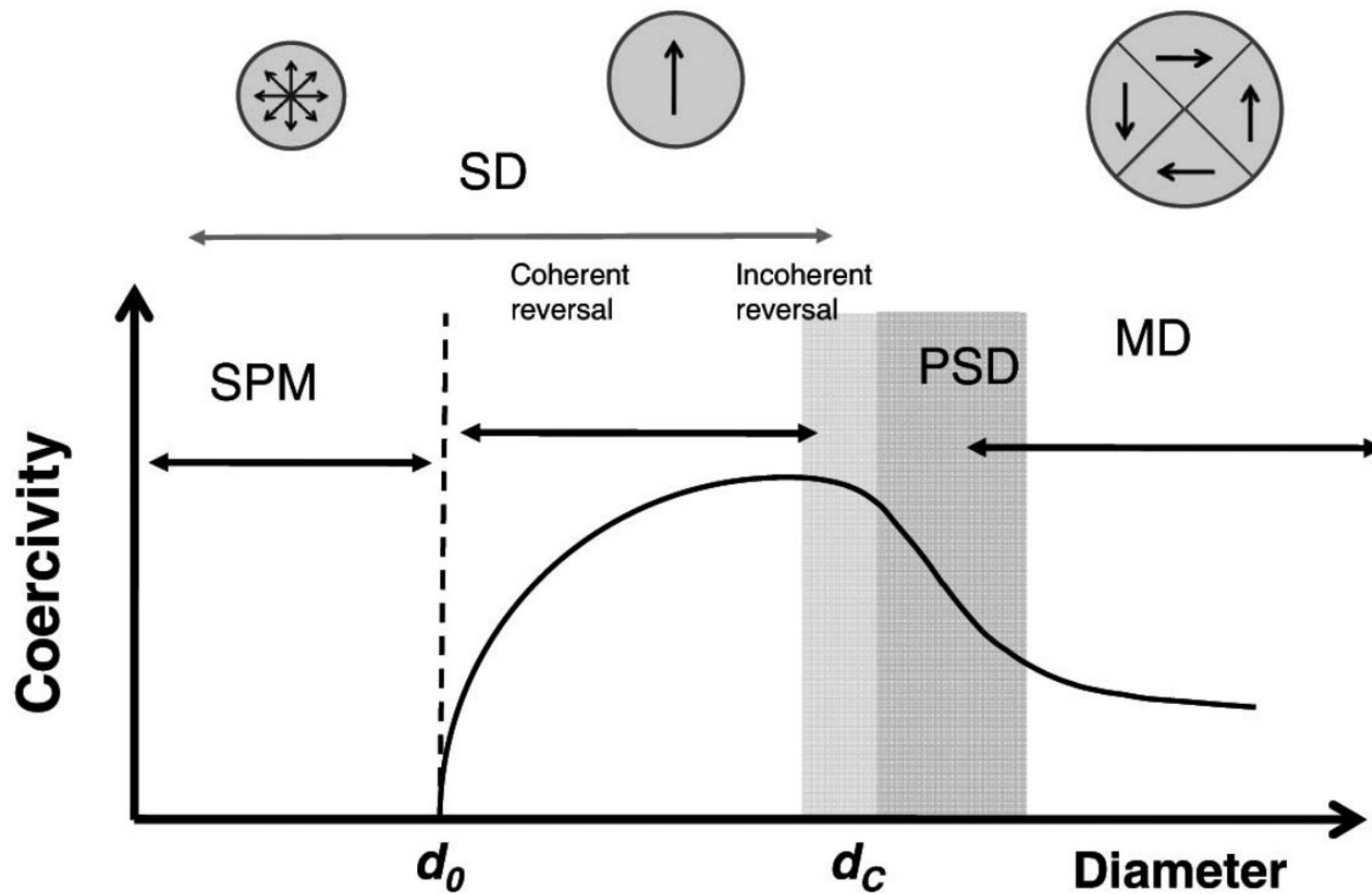
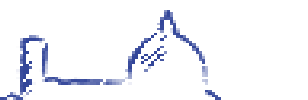


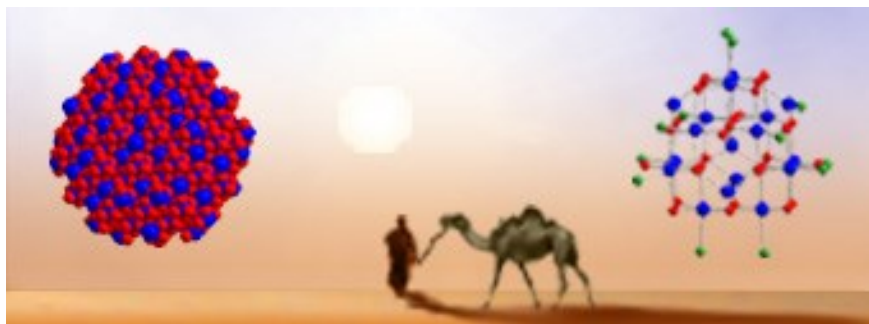
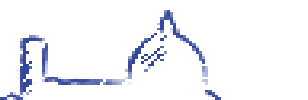
Il tunneling è possibile per valori di campo $H=nD/g\mu_B$



$H=nD/g\mu_B$







Angewandte
Minireviews

D. Gatteschi et al.

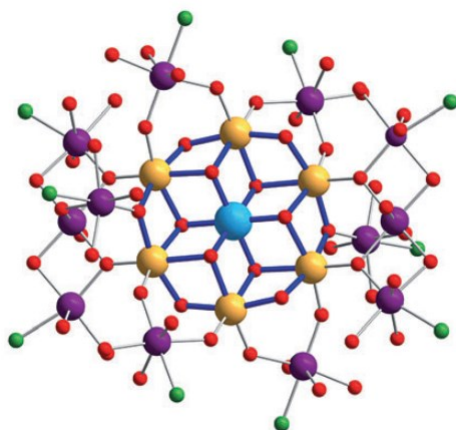
Nanomagnetism

DOI: 10.1002/anie.201105428

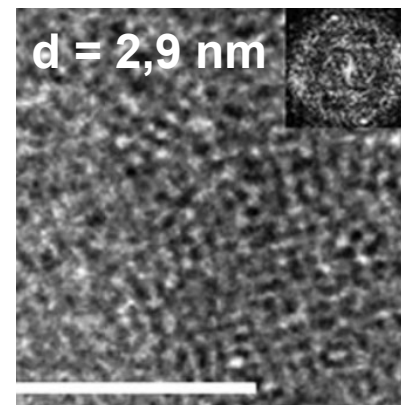
Exploring the No-Man's Land between Molecular Nanomagnets and Magnetic Nanoparticles

Dante Gatteschi,* Maria Fittipaldi, Claudio Sangregorio, and Lorenzo Sorace

Fe₁₉



γ -Fe₂O₃



MNPs

SMM

**NANOPARTICELLE
MAGNETICHE: descritte da
MODELLI CLASSICI**



APPROCCIO TOP-DOWN

Parametri estratti dal bulk

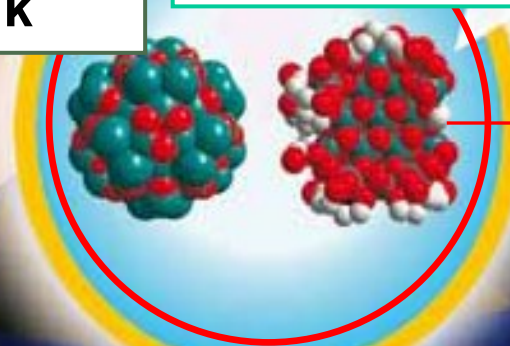
**NANOMAGNETI MOLECOLARI:
descritti da**

MODELLI QUANTISTICI

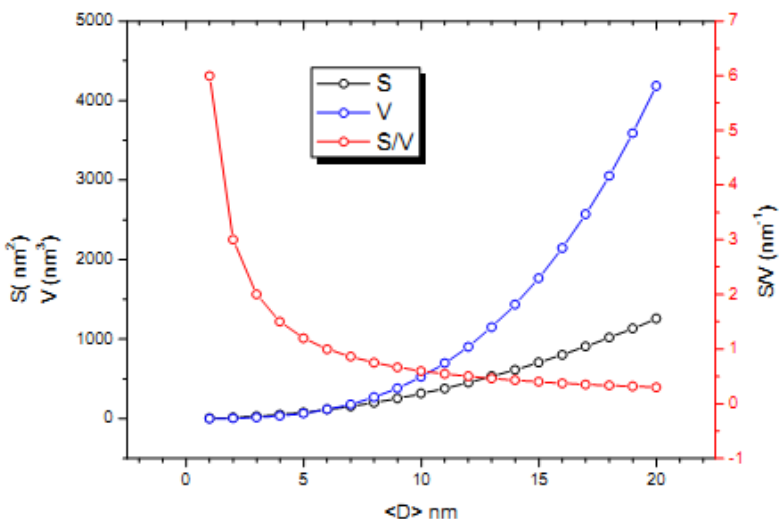
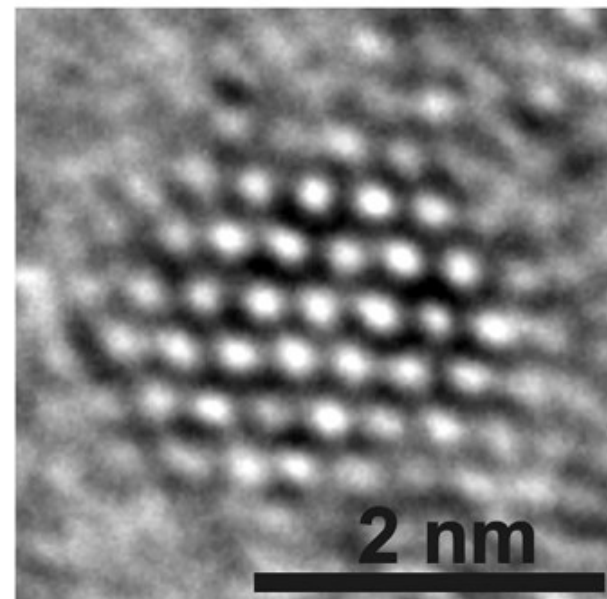
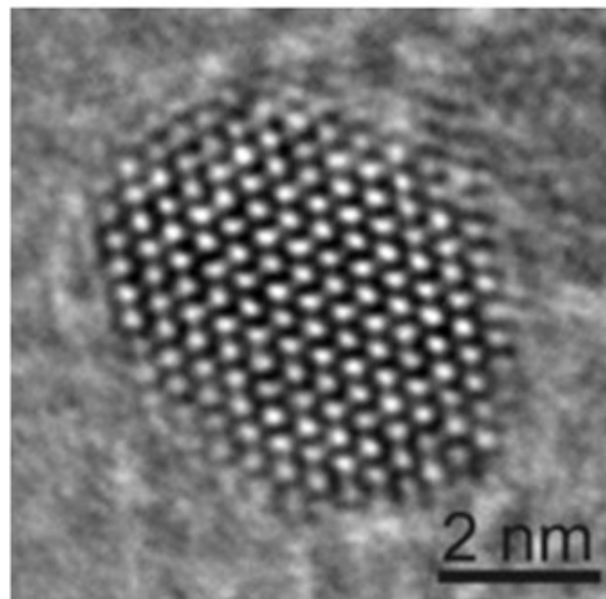
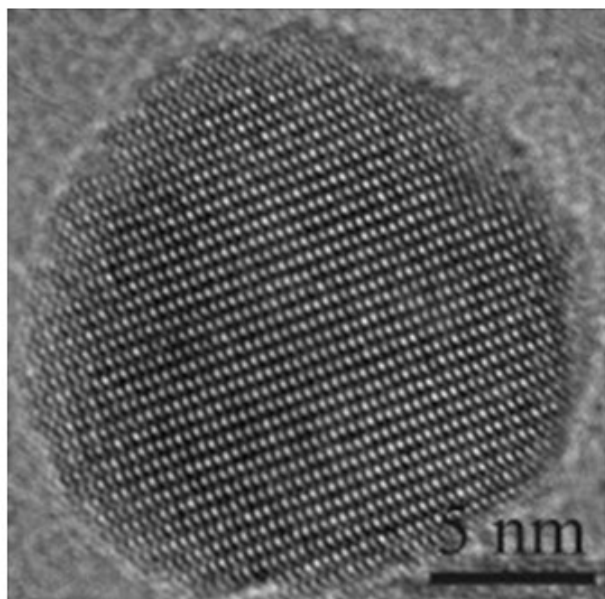
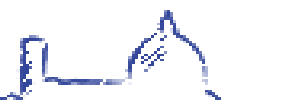


APPROCCIO BOTTOM-UP

Parametri dai singoli spin



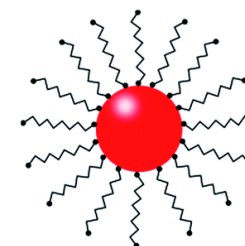
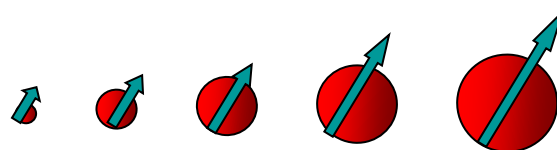
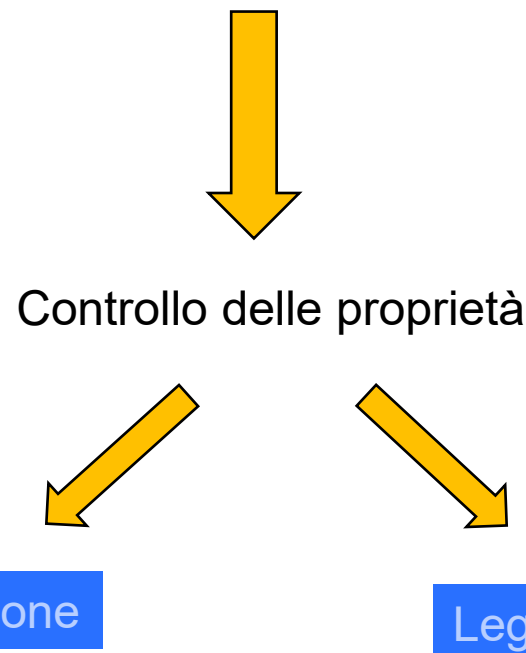
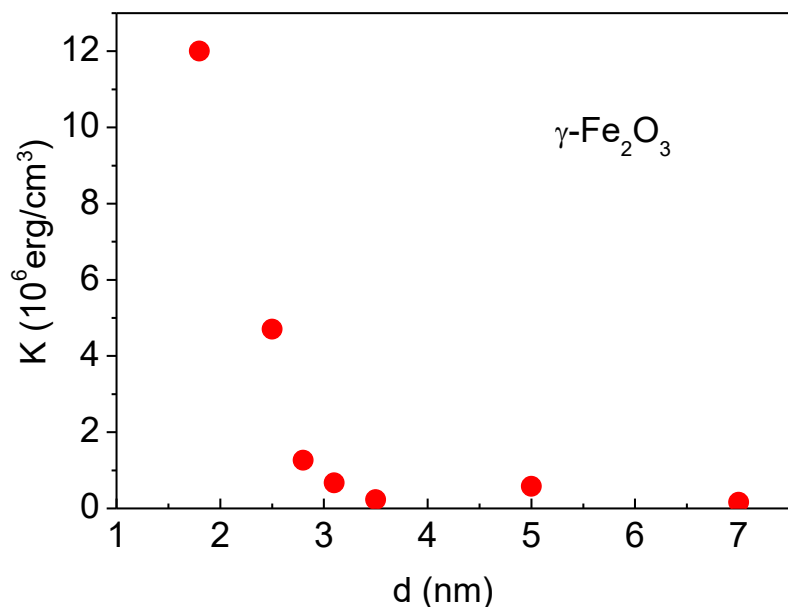
**Nano-
magnete
molecolare**

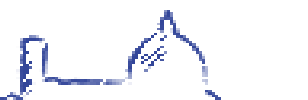


Al diminuire delle dimensioni delle nanoparticelle la percentuale di atomi sulla superficie aumenta fortemente

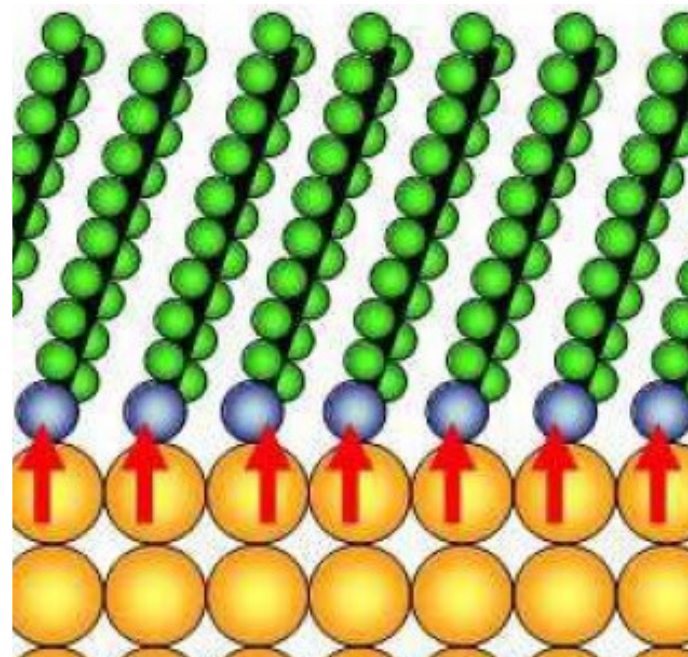
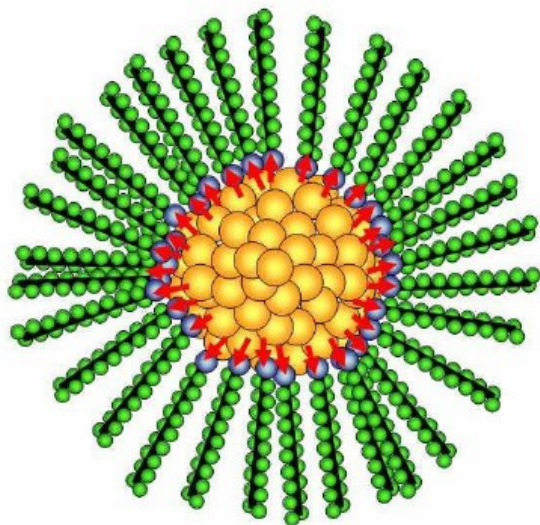


La rottura di simmetria alla superficie può causare variazioni nella struttura a bande, parametri reticolari o coordinazione (anisotropia di superficie, magnetizzazione di saturazione, anisotropia di scambio superficie/core)

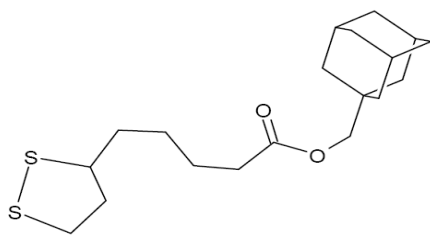
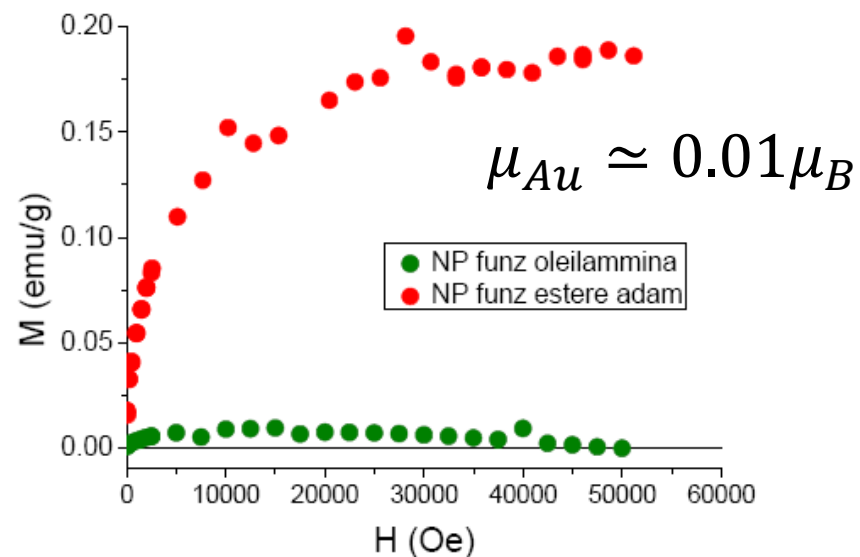
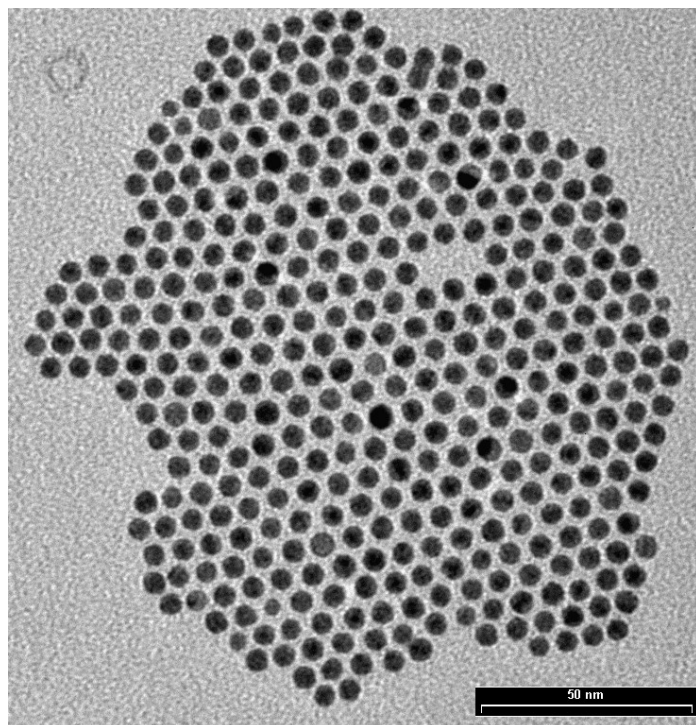
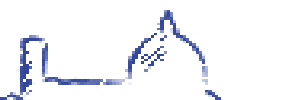




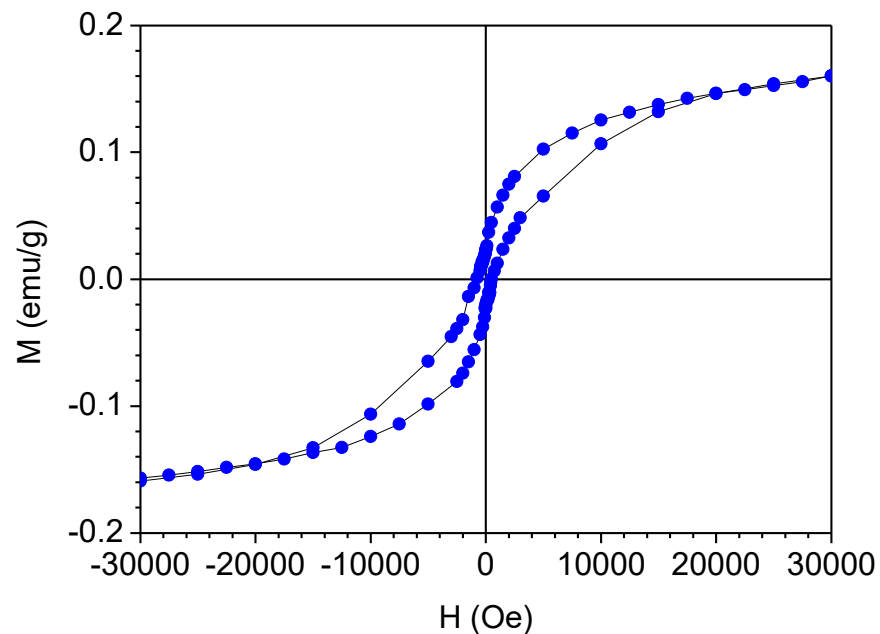
- Charge transfer da Au ad S
- La banda d reca una vacanza che genera un momento magnetico



Forte anisotropia
(non zero coercitività a temperatura ambiente)

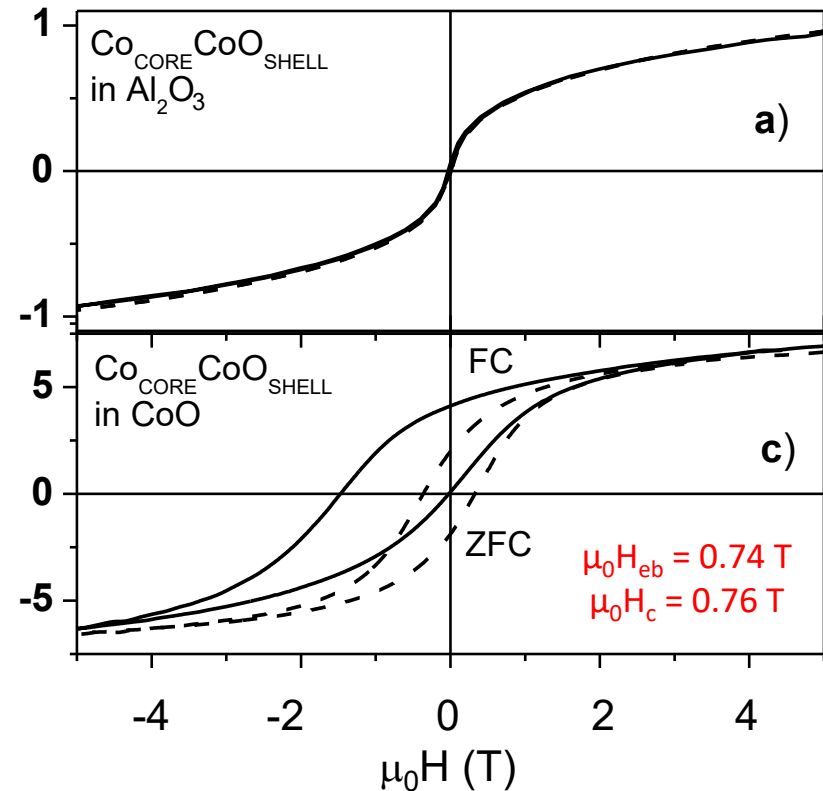
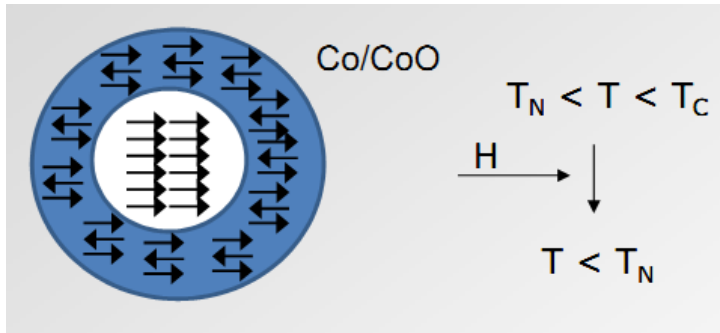
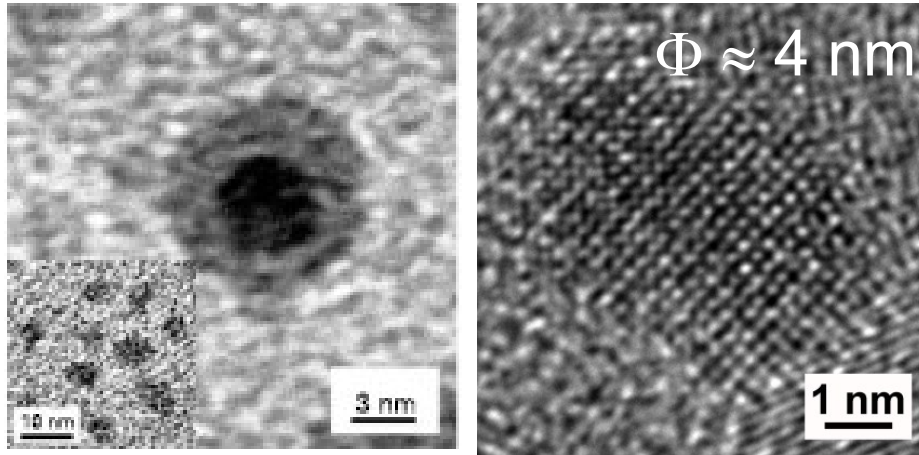


Adamantil-1-metil-5-(1,2ditiolan)pentanoato



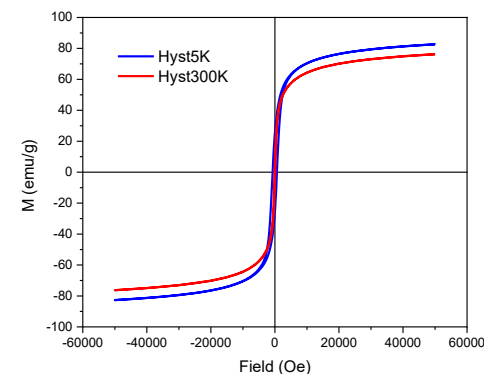
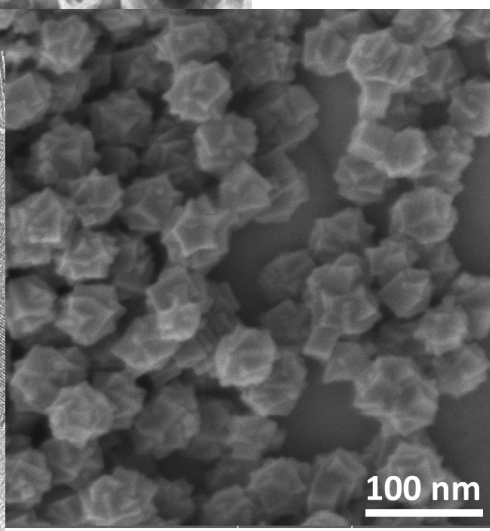
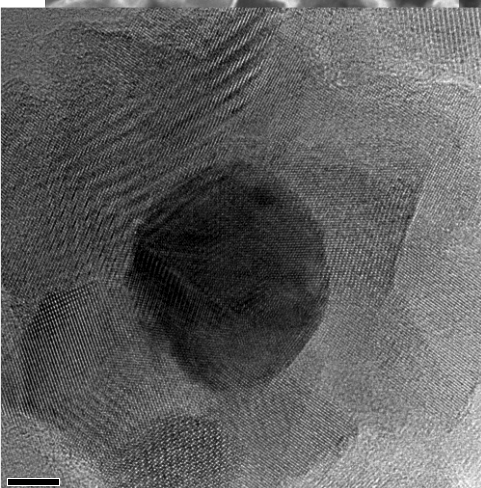
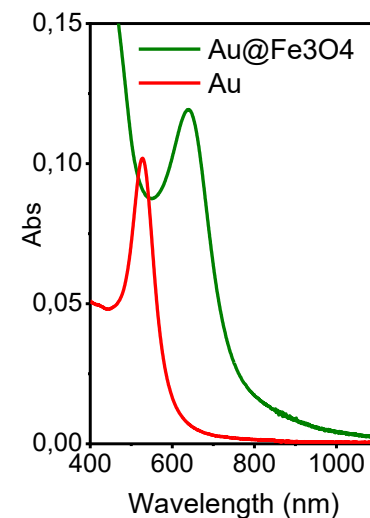
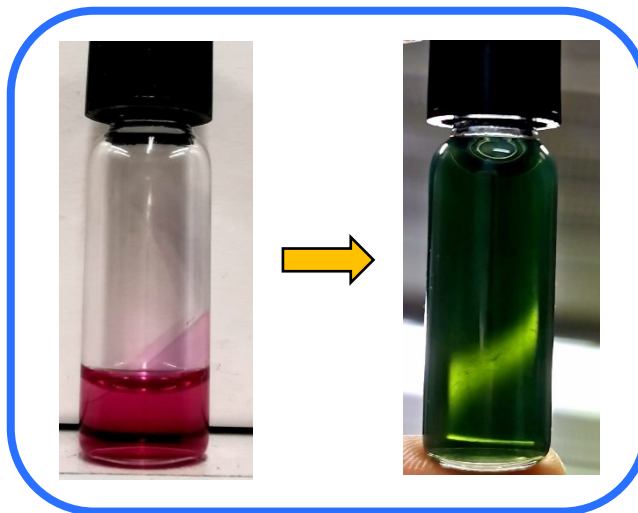
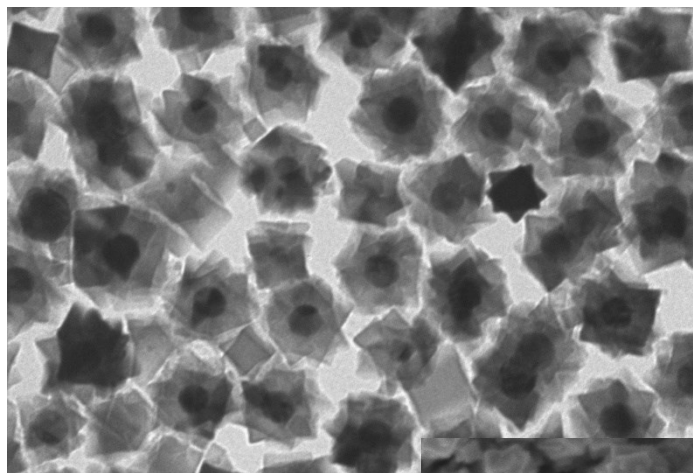
Anisotropia di scambio in Co NPs

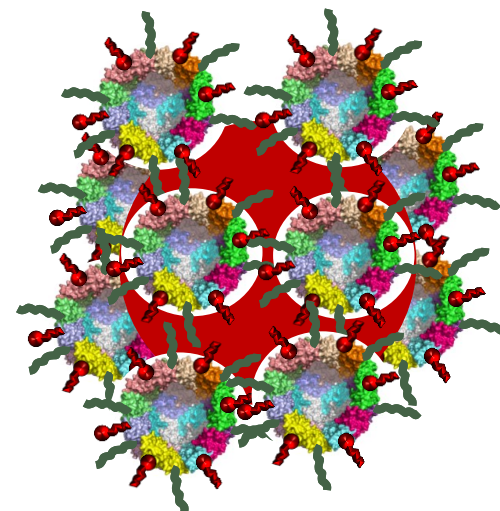
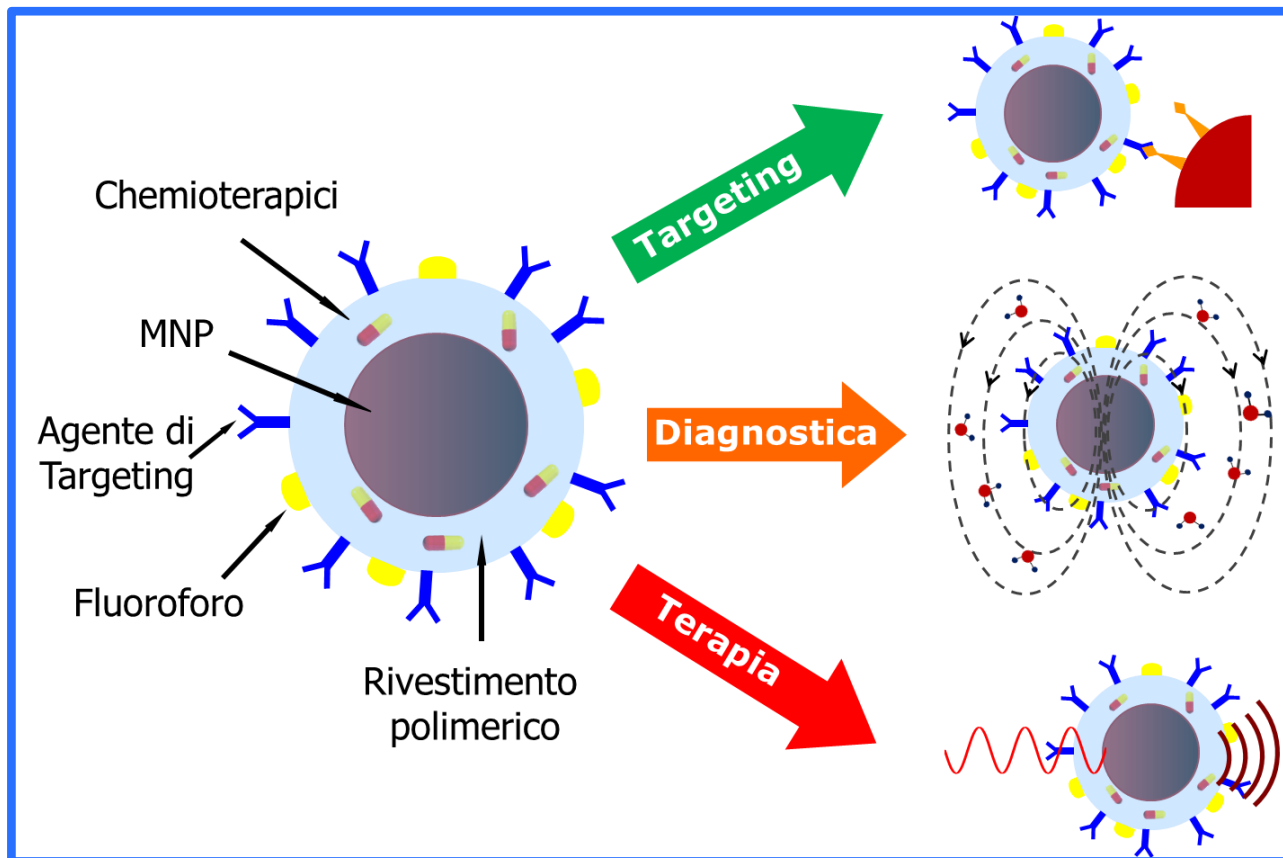
V. Skumryev et al. *Nature* 423, 850, 2003



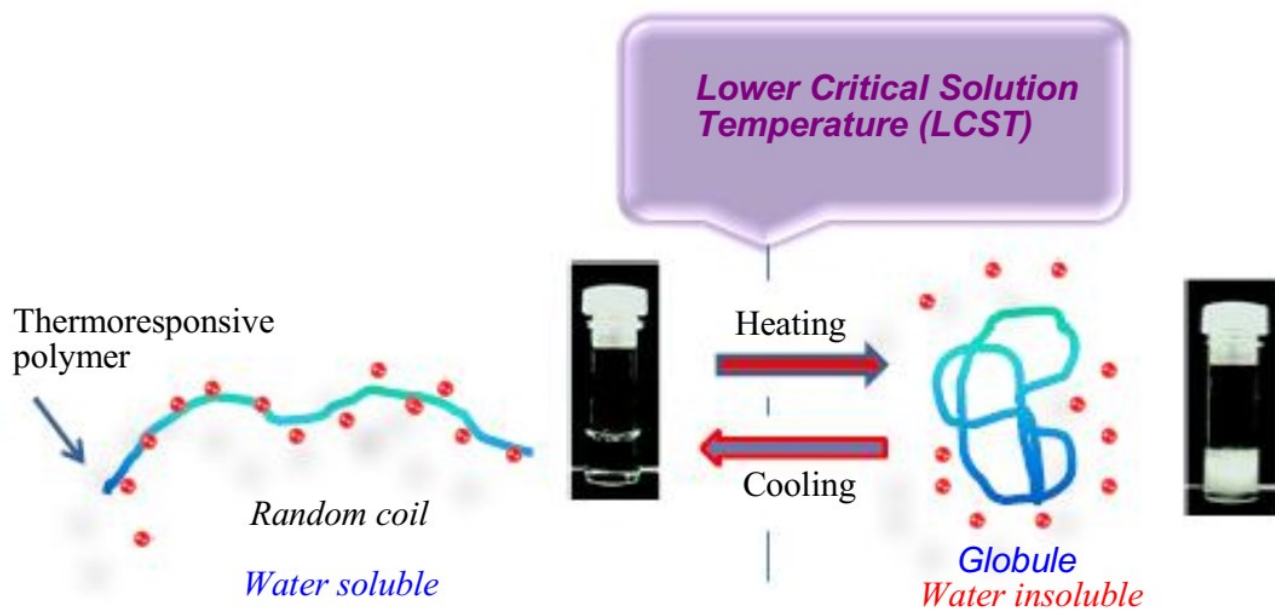
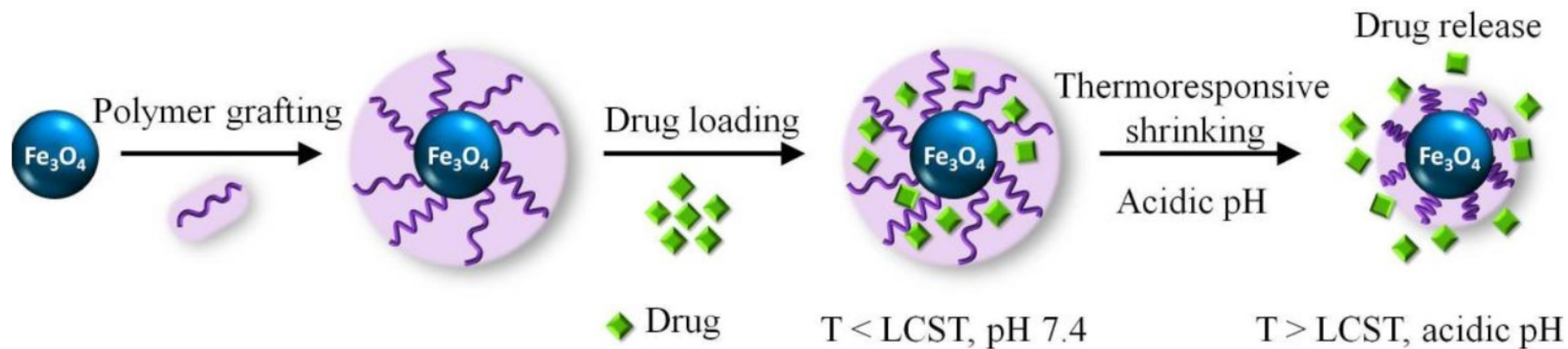
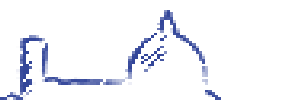
Cicli di istesi a 4.2 K di NP Co_{core}CoO_{shell} NPs di 4 nm in diverse matrici dopo procedure ZFC e FC in campo da 5 T.

Multifunzionalità Au@Fe₃O₄ nanostelle

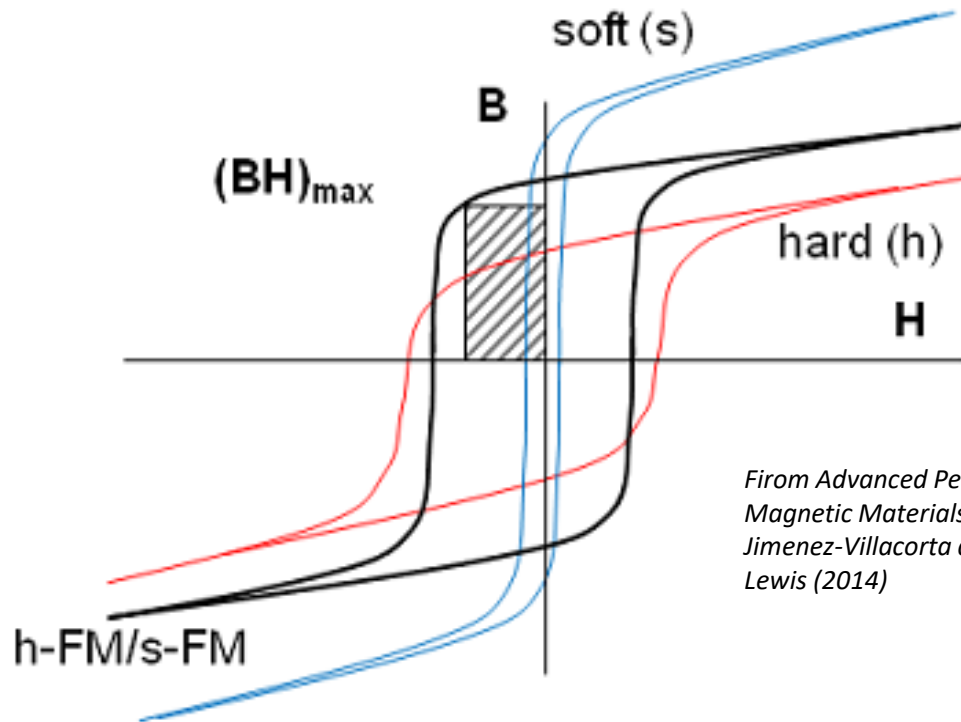
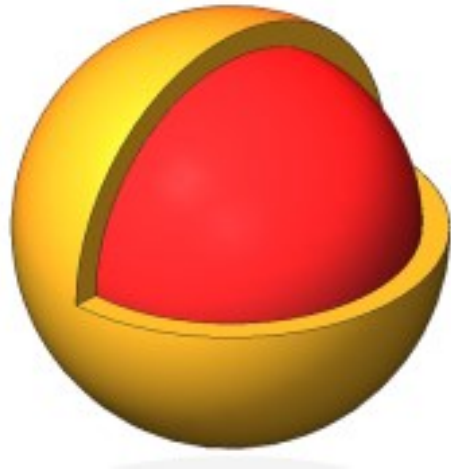




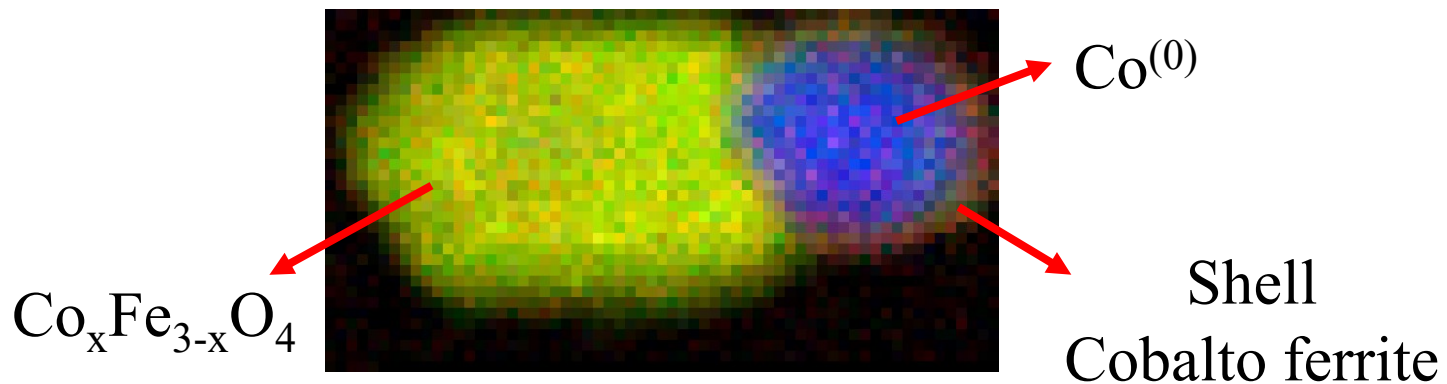
Smart nanocarriers



Nuovi materiali – Exchange spring



From *Advanced Permanent Magnetic Materials* F. Jimenez-Villacorta and L.H. Lewis (2014)





Grazie per l'attenzione